RF LDMOS DEVICE AND METHOD OF FORMING THE SAME

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application claims the priority of Chinese patent application number 201210521428.1, filed on Dec. 7, 2012, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention relates generally to semiconductor devices, and in particular, to a laterally diffused metal oxide semiconductor (LDMOS) device usable in radio frequency (RF) applications.

BACKGROUND

[0003] RF LDMOS devices are commonly used in RF base stations and RF broadcast stations. Manufacturers are always pursuing RF LDMOS devices having a high breakdown voltage, low on-resistance and low parasitic capacitance.

[0004] FIG. **1** shows an existing RF LDMOS device, which can be either a P-channel or N-channel one. In the case of an N-channel RF LDMOS device, as illustrated in FIG. **1**, the reference number **1** represents a heavily-doped P-type substrate whereon a lightly-doped P-type epitaxial layer **2** is formed. In the lightly-doped P-type epitaxial layer **2**, there is sequentially formed a heavily-doped N-type source region **8**, a P-type channel region **7** and an N-type drift region **3**, in this order in a side-by-side manner, with a heavily-doped N-type drain region **9** formed in the N-type drift region **3**. The P-type channel region **7** and the N-type drift region **3** are overlaid by a gate oxide layer **4** and a uniformly-doped polysilicon gate electrode **5** and stacked in the order from the bottom up. The polysilicon gate electrode **5** and a portion of the N-type drift region **3** are covered by a silicon oxide layer **10**, and a portion of the silicon oxide layer **10** is further covered by a gate shield layer **11** which extends above at least a portion of the N-type drift region **3** while being isolated by the silicon oxide layer **10**. A sinker region **12** extends downwards from a surface of the source region **8**, through the source region **8** and the epitaxial layer **2**, into the substrate **1**.

[0005] In the existing RF LDMOS device, the gate shield layer **11** is generally fabricated from metal or heavily-doped N-type polysilicon and can hence cause a reduced surface field (RESURF) effect which is capable of effectively increasing the breakdown voltage and effectively reducing the gate-drain parasitic capacitance of the device, thereby allowing the N-type drift region **3** to be relatively heavily doped to decrease the on-resistance of the device.

[0006] However, a high dopant concentration of the N-type drift region **3** may also lead to some consequences detrimental to the reliability of the device, in particular the intensification of the so-called hot carrier injection (HCI) effect. What can intensify the HCI effect is the strengthening of an originally high transverse electric filed in the N-type drift region **3** caused by the dopant concentration increase therein in the even of a high voltage being applied on the heavily-doped N-type drain region **9**.

[0007] One way of improving the HCI effect is by increasing the thickness of the gate oxide layer **4**, but this will also lead to an increase in the on-resistance of the device. Another way is to lower the dopant concentration of the N-type drift region **3**. However, this approach will decrease the on-resistance of the device. Furthermore, while making a step-shaped gate oxide layer **4** whose thickness is larger in one section proximal to the drain region **9** than in the other section near to the source region **8** can enable an unchanged on-resistance of the device even when the N-type drift region **3** is heavily doped, such a complex structure of the step-shaped gate oxide layer **4** will increase the complexity of the fabrication process.

SUMMARY OF THE INVENTION

[0008] The invention seeks to provide an RF LDMOS device that can be easily manufactured and is capable of mitigating the HCI effect while not increasing the on-resistance. The invention also seeks to provide a method of forming such an RF LDMOS device.

[0009] In a first aspect of the invention, there is provided an RF LDMOS device including: a gate structure on a surface of a substrate; and a source region and a drain region beneath the surface of the substrate, the source region and the drain region formed on opposite sides of the gate structure, wherein the gate structure includes a first section proximal to the source region and a second section proximal to the drain region, and wherein the first section of the gate structure has a dopant concentration at least one decimal order higher than a dopant concentration of the second section of the gate structure.

[0010] In a preferred embodiment, each of the first section and the second section may have a width equal to half of a width of the gate structure.

[0011] In a preferred embodiment, the first section of the gate structure may be heavily doped with a dopant concentration of 1×10^{20} atoms/cm^3 to 1×10^{21} atoms/cm^3, while the second section of the gate structure may be moderately doped with a dopant concentration of 1×10^{18} atoms/cm^3 to 1×10^{19} atoms/cm^3.

[0012] In a second aspect of the invention, there is provided a method of forming an RF LDMOS device. The method includes the steps of: forming a gate structure on a surface of a substrate and forming a source region and a drain region beneath the surface of the substrate, wherein the source and drain regions are formed on opposite sides of the gate structure; and doping the gate structure to make a first section of the gate structure proximal to the source region have a dopant concentration at least one decimal order higher than a dopant concentration of a second section of the gate structure proximal to the drain region.

[0013] In a preferred embodiment, doping the gate structure may include: performing a first doping process on both of the first section and the second section; and covering the second section with a photoresist and performing a second doping process only on the first section to make the first section have a dopant concentration at least one decimal order higher than a dopant concentration of the second section.

[0014] In a preferred embodiment, the first doping process may be performed prior to the second doping process and after forming the gate structure.

[0015] In a preferred embodiment, the first doping process may be an in-situ doping process performed during forming the gate structure.

[0016] With the gate structure containing two sections having different dopant concentrations, the RF LDMOS device of the present invention has several advantages over those of the prior art.